



## *Crop Research at NASA's Kennedy Space Center*



# ***Food and Crop Research Activities Kennedy Space Center, FL***

*June 2005*

*Ray Wheeler*

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## *Crop Research at NASA-KSC*

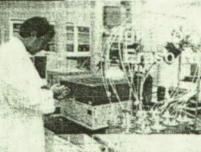


**KSC Crop  
Research  
Team**



**Oscar  
Monje**

**Hyeon-Hye  
Kim**



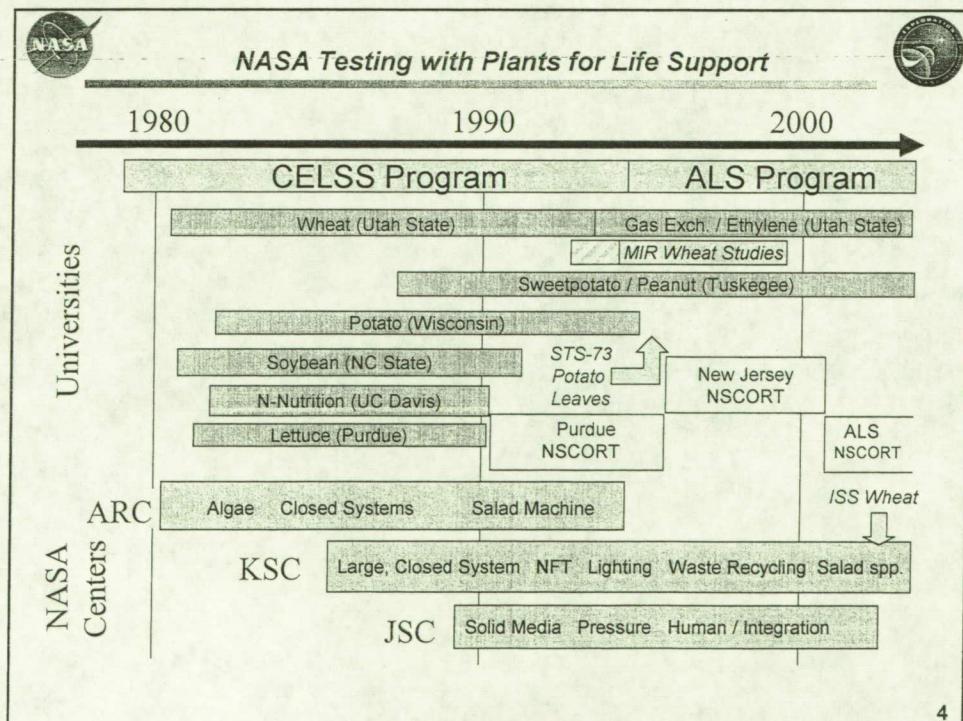
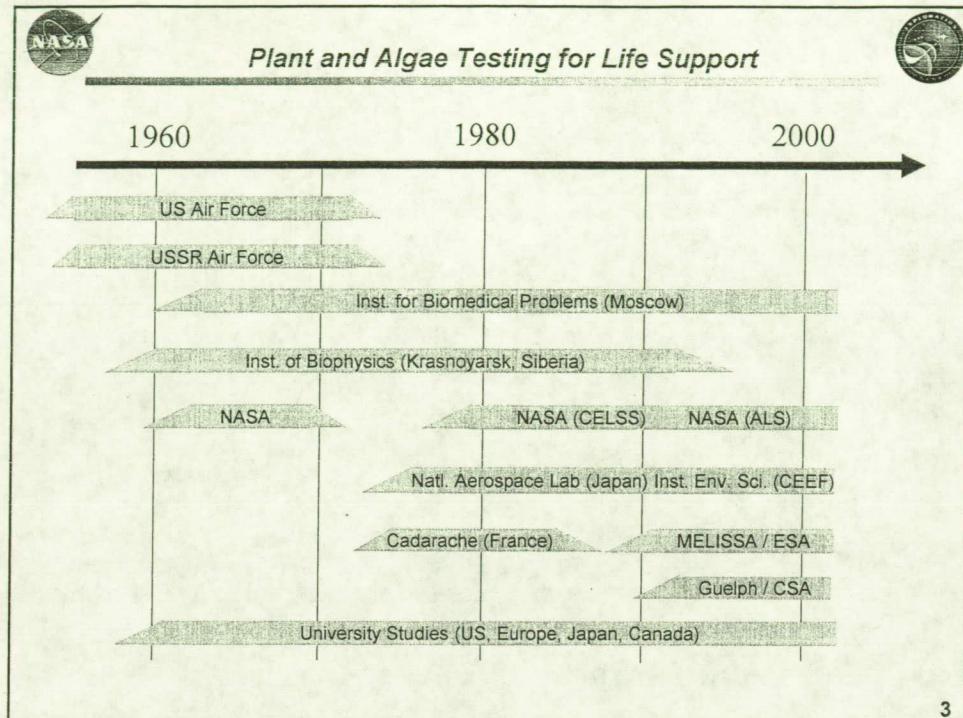
**Ray  
Wheeler**

**Sharon  
Edney**

**John  
Sager**

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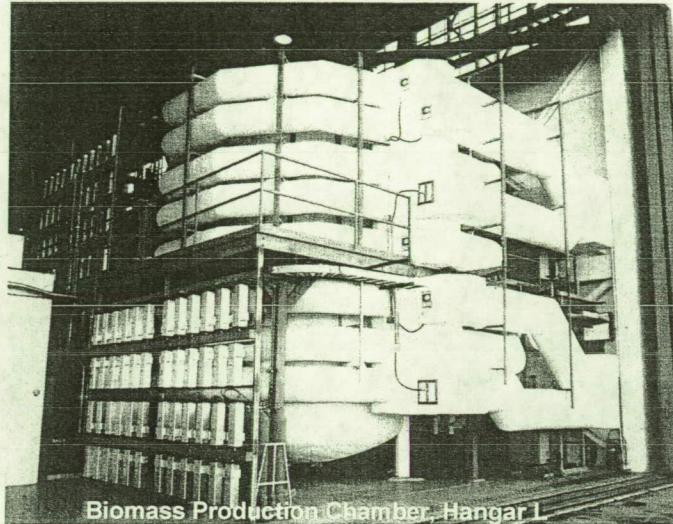




## Crop Research at NASA-KSC



⇒ KSC's Crop Research Began in Hangar L ca. 1985  
for the CELSS Program

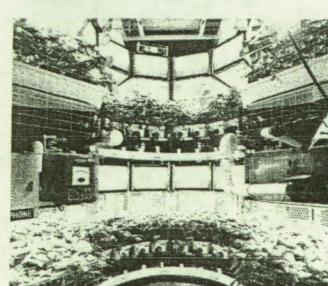
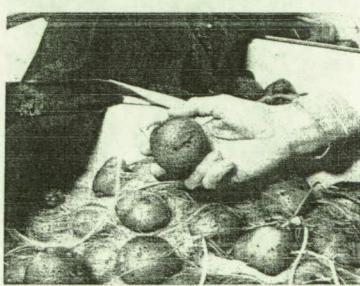


Biomass Production Chamber, Hangar L.

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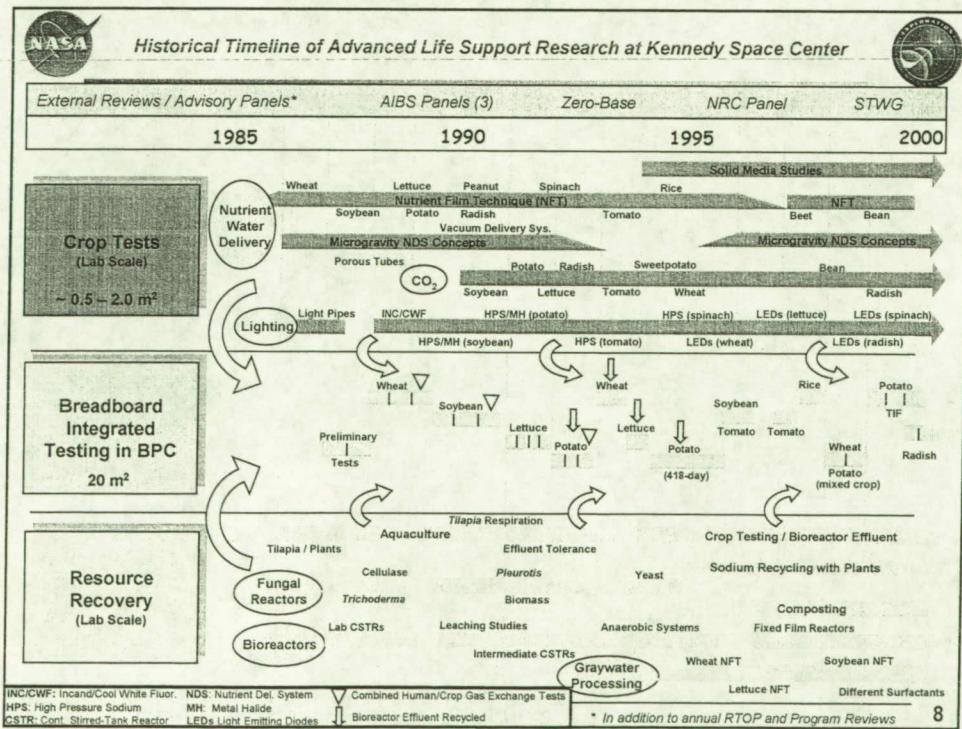
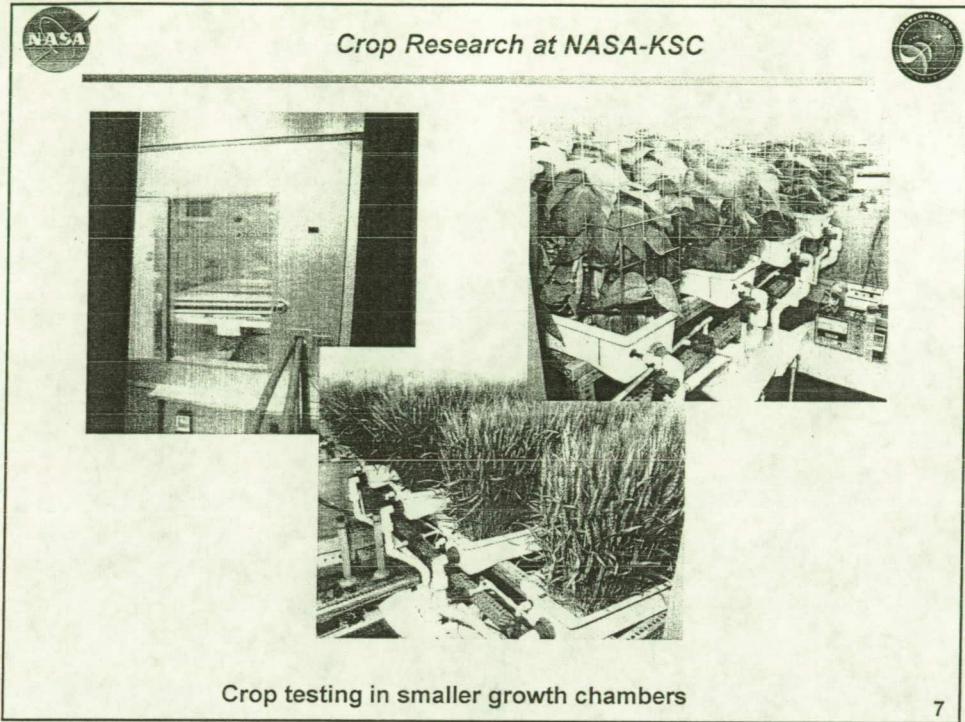


## Crop Research at NASA-KSC



Biomass Production Chamber Studies

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## Crop Research at NASA-KSC



### Current Crop Research Activities:

- ALS Technology Development Proposal / Technical Task Agreements
  - Environmental Responses of ALS Crops
  - Cultivar Comparison / Selection
  - Mixed vs. Monoculture
- NRA Grants
  - PESTO / ISS Flight Experiment (Gary Stutte)
  - RASTA / VOCA (Gary Stutte)
  - WONDER Flight Experiment (Howard Levine)
- National Research Council (Hyeon-Hye Kim)
  - Plant Growth Under LED lighting
- Graduate Student Research Program
  - Cornell, Univ. Florida, Univ. Arkansas, Texas Tech.

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## Crop Research at NASA-KSC



### TTA Progress:

#### Environmental Response Tests\*

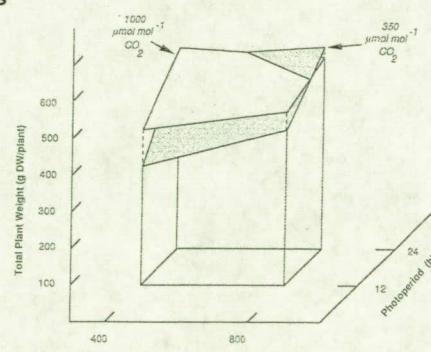
Light:  $\mu\text{mol m}^{-2} \text{s}^{-1}$  :  
150, 300, 450

$\text{CO}_2$  (ppm) :  
400, 1200, 4000

Temp. ( $^{\circ}\text{C}$ ) :  
22, 25, 28

#### Target Crops:

- 1) Lettuce, Radish, Onion
- 2) Tomato, Pepper
- 3) Strawberry



\* Underlined values indicate conditions typical for open chambers in space cabin

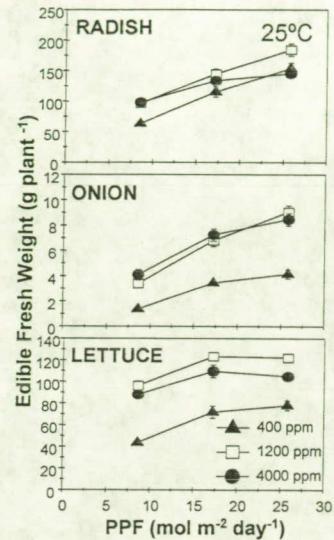
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## Crop Research at NASA-KSC



### TTA Progress: Environmental Response Tests



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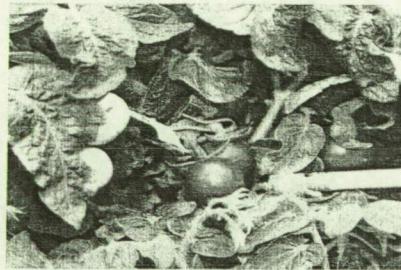
## Crop Research at NASA-KSC



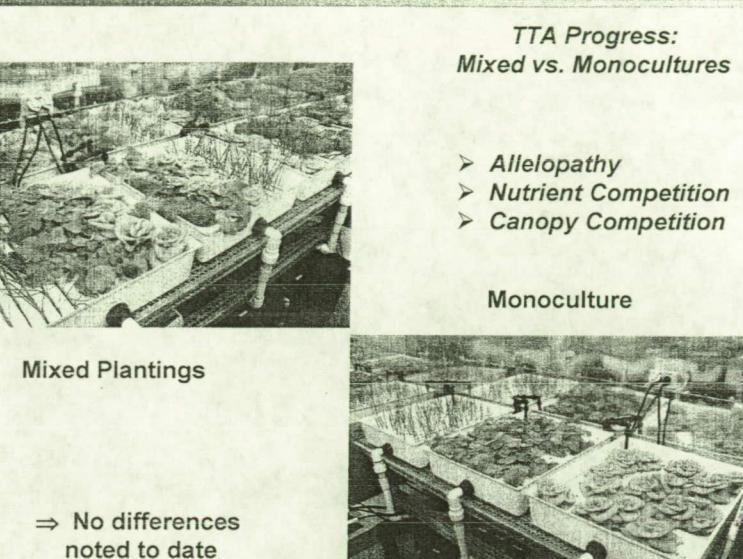
### TTA Progress Cultivar comparisons:

- Lettuce: Waldmanns' Green, Ostinata, Flandria, (Red Sails, Eruption, Outredgeous)
- Onion: Kinka, Kruncho, Choho, Choetsu, Guardsman, Pacific Pearl, Evergreen Hardy White, Deep Purple
- Radish: Cabernet, Fireball, Cheriette, Giant White Glove, Cherry Belle, Sora, Cherry Bomb II, Vintage
- Tomato: MicroTina, Florida Petite, Red Robin
- Pepper: Triton, Hanging Fruit Basket, False Alarm

*(underlined indicates the cultivar chosen for further testing)*



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**TTA Progress:  
Mixed vs. Monocultures**

**Mixed Plantings**

→ No differences noted to date

**Monoculture**

➤ Allelopathy  
➤ Nutrient Competition  
➤ Canopy Competition

**Crop Research at NASA-KSC**

**LED Lighting Studies**

**Green Light for Human Vision and Better Canopy Penetration**

**C.I.E. CHROMATIC DIAGRAM**

**24 h after exposure**

**24 h after return to CWF**

Stomatal conductance ( $\text{mol m}^{-2} \text{s}^{-1}$ )

Treatment	Stomatal conductance ( $\text{mol m}^{-2} \text{s}^{-1}$ )
24 RB	~0.12
24 RGB	~0.10
24 GF	~0.05
24 CWF	~0.12
25 RB	~0.10
25 RGB	~0.10
25 GF	~0.10
25 CWF	~0.10

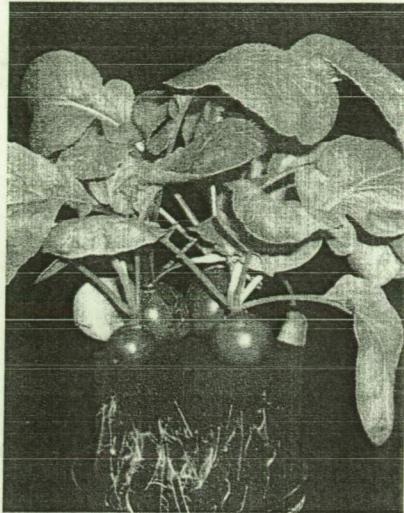
**Stomatal Responses to Spectra**



## Crop Research at NASA-KSC



- RASTA / VOCA Project:
  - Team: Gary Stutte (PI), Ignacio Eraso, Sylvia Anderson
  - Originally a flight experiment to study effects of volatile organic compounds (VOCs) in closed flight chambers on plant growth (RASTA).
  - Transitioned to a Ground – Based project to study volatile organic compounds produced in closed systems, and their effects on plants growth (VOCA)
- ⇒ Development of a "SMAC" scale for plants



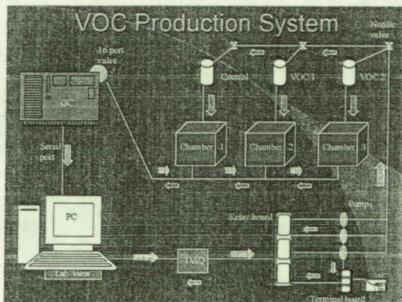
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## Crop Research at NASA-KSC



### RASTA / VOCA...Exposure and Collection Chambers

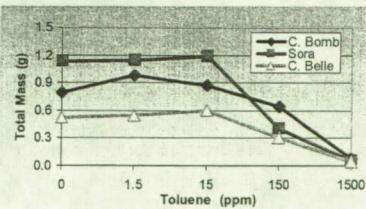


Exposure Chambers



#### Target VOCs:

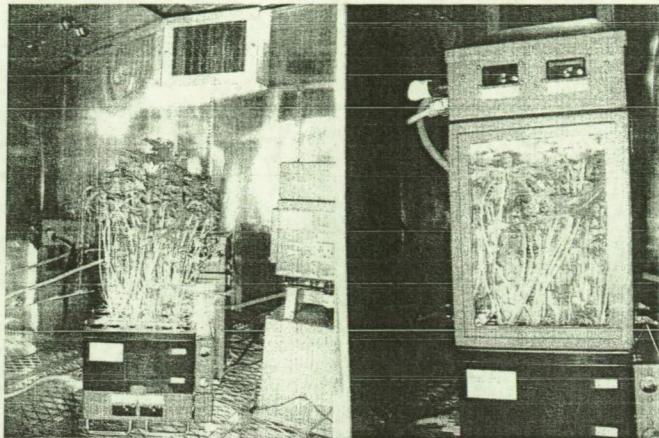
- Ethylene ( $10^{-4}$  SMAC)
- Ethanol ( $10^{-2}$  SMAC)
- Methanol ( $10^{-1}$  SMAC)
- Toluene ( $>0$  SMAC)
- Acetone ( $>0$  SMAC)



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## Crop Research at NASA-KSC



LADA Microbial Risk Assessment  
Jay Garland, co-Investigator  
(Gail Bingham, Principal Investigator)

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## Crop Research at NASA-KSC



- **Food Analysis and Testing**
  - Proximate Composition
    - Protein, Fat, CHO, Ash, (Dietary Fiber)
  - Elemental Composition
  - Antinutrients
    - Nitrate, Phytic Acid, Oxalic Acid
  - Antioxidants
    - Vit. E and C, Anthocyanins, Lycopene, Polyphenols
  - Sensory Evaluations
    - Taste Test Panels at JSC

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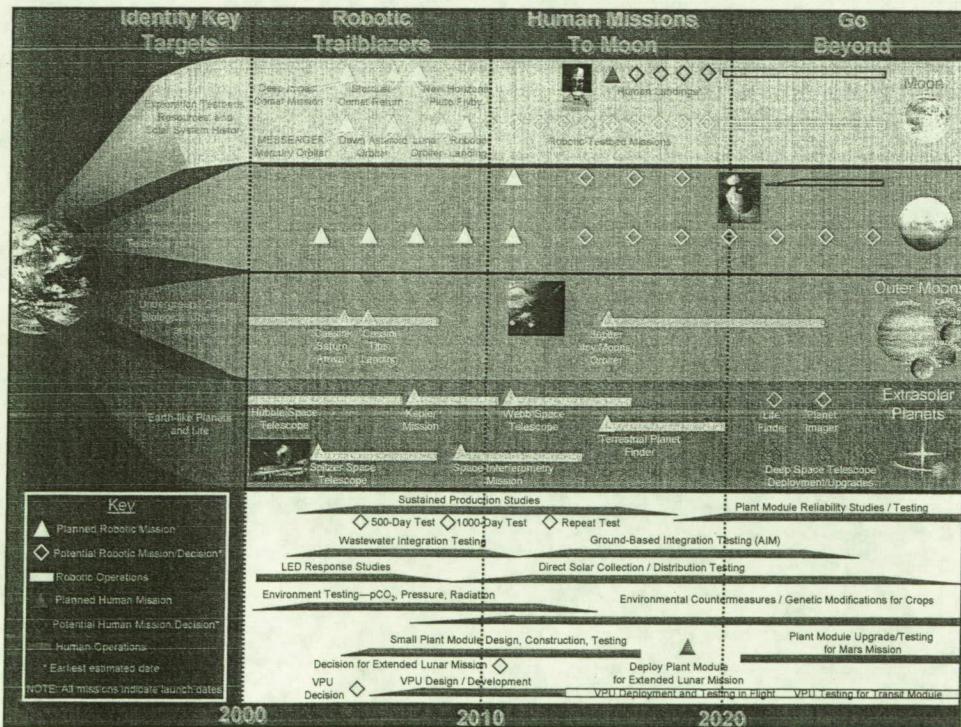


## Crop Research at NASA-KSC



- Crop Production Activities (existing in black and proposed in red)
- Environmental Testing with
  - Continue Lettuce, Radish, Onion, Tomato, and Pepper
  - Initiate Strawberry Testing
  - Initiate Pressure Response Testing at Univ. of Guelph
- Cultivar Selection
  - Complete strawberry testing
  - Initiate GMO Strategy and Development
- Mixed / Monoculture
  - Continue Lettuce-Onion-Radish / Tomato-Pepper
  - Initiate Long-Duration, Sustained Production Trials
- Continue LED Testing
  - Design and Develop Solar Light Capture / Delivery Systems
- Continue Food Quality and Sensory
- Continue VOC Response Testing / Plant SMAC
- Initiate VPU Development
- Support Psychological Response Studies (Human/Plant)
  - Terrestrial Analogues, e.g., McMurdo Station, Antarctica
- Initiate Crop Radiation Response Studies
- Initiate Integrated Crop, Wastewater, Solid Waste Testing
- Initiate Planetary Surface Chamber Design and Development

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## Crop Research at NASA-KSC



### Meetings / Presentations for 2004:

- Intl. Conference on Environmental Systems
- Habitation Society
- Plant Growth Regulator Society of America
- American Society for Horticultural Science
- Intl. Controlled Environment Working Group (NCR-101)
- Int. Society of Horticultural Science
- Agronomy Society of America
- Committee on Space Research (COSPAR)
- International ALS Working Group
- American Society for Gravitational and Space Biology

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## Crop Research at NASA-KSC



### Crop Publications with KSC Authors for 2004/2005:

1. Berkovich, Yu.A., A.N. Erokhin, S.O. Smelashina, J.J. Prenger, and H.G. Levine. 2004. Development and testing of a cylindrical LED lighting unit for a conveyer-type plant production system. *SAE Tech. Paper* 2004-01-2434.
2. Bucklin, R.A., P.A. Fowler, V.Y. Rygina, R.M. Wheeler, Y. Yu, L. Huang, and E.G. Wilkerson. 2004. Greenhouse design for the Mars environment: Development of a prototype deployable dome. *Acta Horticulturae* 655:127-134.
3. Kim, H-H., G.D. Goins, R.M. Wheeler, and J.C. Sager. 2004. Stomatal of lettuce grown under or exposed to different light qualities. *Annals of Botany* 94:691-697.
4. Kim, H-H., R.M. Wheeler, J.C. Sager, and G.D. Goins. 2004. A comparison of growth and photosynthetic characteristics of lettuce grown under red and blue light with and without supplemental green light. *Acta Horticulturae* 659:467-475.
5. Kim, H-H., R.M. Wheeler, J.C. Sager, N.C. Yorio, and G.D. Goins. 2005. Lighting emitting diodes as an illumination source for plants: A review of research at a Kennedy Space Center. *Habitation* 10(2):7-17.
6. Kim, H-H., R.M. Wheeler, J.C. Sager, and J.H. Norikane. 2005. Photosynthesis of lettuce exposed to different short term light qualities. *Environment Control and Biology* (in press).
7. Krishnamoorthy, V., L.H. Levine, C. Zhou, and P.W. Pare. 2004. In vitro flavon-3-ol oxidation mediated by a B ring hydroxylation pattern. *Chem. Res. Toxicol.* 17:793-798.
8. Goins, G.D., N.C. Yorio, and R.M. Wheeler. 2004. Influence of nitrogen nutrition management on biomass partitioning and nitrogen use efficiency in hydroponically-grown potato. *J. Amer. Soc. Hort. Sci.* 129:134-140.
9. Norikane, J.H., S.B. Jones, S.L. Steinberg, H.G. Levine, and D. Or. In press. Porous media matric potential and water content measurements during parabolic flight. *Habitation* 10(2):117-126.
10. Paul, A-L., H.G. Levine, W. McLamb, K. Norwood, G. Stutte, D. Reed and R.J. Ferl. In press. Plant molecular biology in the space station era: utilization of the International Space Station. *Adv. Space Research* (Astrophysics).
11. Prenger, J.J., S.L. Steinberg, D. Haddock, J.H. Norikane, and H.G. Levine. 2004. Accuracy of a point source thermal soil moisture sensor for space flight nutrient delivery systems. *SAE Tech. Paper* 2004-0-2456.
12. Prenger, J.J., H-H. Kim, J.T. Richards, O. Monje, H.G. Levine, N. Yorio, G. Stutte, R. Wheeler, and J. Sager. In press. Crop production in an extraterrestrial (controlled-environment, microgravity) environment. *J. Agricultural Meteorol.* 60(6):385-390.
13. Prenger, J.J., S.L. Steinberg, D. Haddock, J.H. Norikane, and H.G. Levine. 2004. Accuracy of a point source thermal soil moisture sensor for space flight nutrient delivery systems. *SAE Tech. Paper* 2004-0-2456.
14. Richards, J.T., N.C. Yorio, S.L. Edney, C.E. Yunker, and G.W. Stutte. 2004. Evaluating growth characteristics and total anthocyanin content in three cultivars of red romaine-type lettuce (*Lactuca sativa* L.) in response to three lighting intensities. *Proc. Plant Growth Reg. Soc.* 31: (in press)
15. Richards, J.T., S. Edney, N.C. Yorio, G.W. Stutte, R.M. Wheeler, G.D. Goins, N. Cranston. 2004. Effects of lighting intensity and supplemental CO<sub>2</sub> on yield of potential salad crops for ISS. *SAE Tech. Paper* 2004-0-2296.
16. Rutzke, C.J., R.P. Giahn, M.A. Rutzke, R.M. Welch, R.W. Langhans, L.D. Albright, G.F. Combs, Jr., and R.M. Wheeler. 2004. Bioavailability of iron from sprouting canning in a vitro/human Caco-2 cell bioassay model. *Habitation* 10(1):7-14.
17. Rygina, V.Y., P. A. Fowler, R.M. Wheeler, and R.A. Bucklin. 2004. Water cycle and its management for plant habitats at reduced pressures. *Habitation* 10(1):49-68.
18. Schuegerl, A.C., G.A. Capello, J.A. Di Benedetto, C. Mao, C.M. Thai, M.D. Evans, J.T. Richards, T.A. Blank, and E.C. Stryjewski. 2004. Comparison of two hyperspectral imaging and two laser-induced fluorescence instruments for the detection of zinc stress and chlorophyll concentration in *Bahia grass* (*Paspalum notatum* Flugge). *Remote Sensing of Environment* 84:572-588.
19. Stutte, G.W., I. Eraso, and O. Van Den Ende. 2004. Sensitivity of radish to volatile organic compounds: Toluene, ethanol, and acetone. *Proc. Plant Growth Reg. Soc.* 31: (in press)
20. Stutte, G.W., I. Eraso, and P.A. Fowler. 2004. Effects of common ISS volatile organic compounds on growth of radish. *SAE Tech. Paper* 2004-0-2297.
21. Wheeler, R.M., K.A. Corey, G.M. Volk, C.L. Mackowiak, N.C. Yorio, and J.C. Sager. 2004. Soybean canopy gas exchange rates: Effects of lighting. *Eco-Engineering* 16:209-214.
22. Wheeler, R.M. 2004. Horticulture for Mars. *Acta Horticulturae* 642:201-215.
23. Wheeler, R.M., B.V. Peterson, and G.W. Stutte 2004. Ethylene production throughout growth and development of plants. *HortScience* 39 (6):5-9.

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